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AN EXPERIMENTAL COMPARISON OF THREE DIFFERENT SCHEDULES OF REINFORCEMENT OF DRUG ABSTINENCE USING CIGARETTE SMOKING AS AN EXEMPLAR

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The efficacy of three different schedules of reinforcement for promoting and sustaining drug abstinence was compared in this study. Cigarette smoking was studied as an exemplar of stimulant drug self-administration. Sixty cigarette smokers were assigned to one of three groups (progressive rate of reinforcement, fixed rate of reinforcement, and yoked control). Participants in all three groups were asked to refrain from smoking for 1 week. Participants in the progressive and fixed groups achieved greater mean levels of abstinence than those in the control group. Participants in the progressive group were significantly less likely to resume smoking when they became abstinent than participants in the other groups.

DESCRIPTORS: contingency management, substance abuse, nicotine

Drug use is a form of operant behavior that, in part, is maintained by the reinforcing effects of the drug. As such, the probability of using drugs should be influenced by the environmental context in which drug use occurs. More specifically, the availability of alternative nondrug reinforcers should increase drug abstinence if they are available in sufficient magnitude and according to a schedule that is incompatible with drug use (e.g., Higgins, Bickel, & Hughes, 1994). A robust basic-science literature supports these positions and has served as the basis for the contingency-management approach to drug abuse treatment (Bigelow, Stitzer, & Liebson, 1984; Griffiths, Bigelow, & Henningfield, 1980). This approach has been used effectively in the treatment of most forms of drug abuse, including benzodiazepines (Stitzer, Bigelow, & Liebson, 1979), cocaine (Higgins, Budney, et al., 1994; Silverman, Higgins, et al., 1996), nicotine (Stitzer, Rand, Bigelow, & Mead, 1986), and opioids (Stitzer, Iguchi, Kidorf, & Bigelow, 1993).

The main factors that have been manipulated in studies of contingency-management procedures with substance abusers have been the nature of the reinforcer (Stitzer et al., 1993), the type of abused drug (Bigelow et al., 1984), and whether reinforcement is delivered dependent on or independent of abstinence (Higgins, Stitzer, Bigelow, & Liebson, 1986). There has been little investigation of the effects of different schedules of response-dependent reinforcement of drug abstinence (but see Lamb, Iguchi, & Kirby, 1995; Silverman, Wong, et al., 1996). This is surprising considering the wealth of information available on the effects of reinforcement schedules on basic operant behavior (Ferster & Skinner, 1957) and information from other areas of applied behavior analysis suggesting that the schedule of reinforcement can influence the effi-

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cacy of the intervention (e.g., Marcus & Vollmer, 1995; Repp, Felce, & Barton, 1991).

Schedules of reinforcement used in contingency-management interventions for substance abuse treatment are diverse, ranging from relatively simple schedules involving a single contingency (e.g., Stitzer & Bigelow, 1983) to complex schedules involving multiple contingencies (e.g., Higgins, Budney, et al., 1994). Although there is ample evidence that most of these scheduling arrangements are efficacious, there is only limited empirical information available regarding the efficacy of different scheduling arrangements.

The purpose of the present study was twofold: First, we wanted to compare different schedules of reinforcement for sustaining a period of drug abstinence. Second, we wanted to assess further the feasibility of using cigarette smoking as an experimental model for examining the influence of environmental variables on drug abstinence (cf. Stitzer & Bigelow, 1984). We elected to study cigarette smoking because it (a) can serve as a reinforcer (Bickel, DeGrandpre, Hughes, & Higgins, 1991), (b) can be reduced by reinforcing alternative responses (Stitzer & Bigelow, 1984; Stitzer et al., 1986), and (c) is relatively more convenient to study than illicit drug use. Also, cigarette smokers usually relapse within several days of initiating abstinence (Cummings, Jaen, & Giovino, 1985; Hughes et al., 1992). Hence, the factors that control abstinence from cigarette smoking begin to exert their influence shortly after cessation and thus may be examined in short-duration experimental studies. Lastly, cigarette smokers recruited for the present study were not attempting to quit smoking, thereby eliminating the need to provide other clinical services that are usually combined with treatment interventions.

METHOD

Participants

Participants were 60 adults who were recruited for a 5-day study via newspaper ads and fliers posted on bulletin boards. One additional participant was discontinued for reasons unrelated to the study and was subsequently replaced. In order to participate, individuals had to present with an initial carbon monoxide (CO) reading of at least 18 ppm; be over 18 years of age; answer negative to the question, "Are you currently trying to, or do you want to quit smoking?"; and be in good physical and psychiatric health. Participants were not informed of the inclusion criteria except for the age limit. CO was assessed with a MiniCO CO meter (MSA). Psychiatric and physical conditions were assessed in an initial interview in which the following questionnaires were administered: drug-use history, brief psychiatric screen, medical history, and the Fagerstrom Tolerance Questionnaire (Fagerstrom & Schneider, 1989).

Of the 60 participants, 21 were female and 39 were male. The average age was 30 (range, 18 to 70) years. The average number of years of education was 13 (range, 11 to 18). On average, participants smoked 26 cigarettes per day (range, 10 to 50) before the study began and had a Fagerstrom score of 6.5 (range, 4 to 9). Fagerstrom scores are a putative measure of nicotine dependence, with higher scores representing more severe dependence (possible range, 0 to 11; Fagerstrom & Schneider, 1989).

Procedure

Participants were randomly assigned to the progressive rate of reinforcement group (progressive group) and the fixed rate of reinforcement group (fixed group) until the progressive group had 10 participants. This was done in order to have enough participants assigned to the progressive group to

implement a yoked-control procedure with a third group (control group) (Ferster & Skinner, 1957). Subsequent participants were randomly assigned to the three groups until each group contained 20 participants.

At an orientation visit during the week prior to which a participant participated in the study, all participants agreed to visit the laboratory or be visited by us at a place convenient for them, three times per day for 5 days (Monday through Friday) at 9:00 to 11:00 a.m., 3:00 to 5:00 p.m., and 8:00 to 10:00 p.m. All participants were told that there was no way to specify a priori when they would have to stop smoking in order to be abstinent at their initial visit on Monday morning, but our recommendation was that they terminate their smoking on the Friday night immediately before the Monday of the week in which they participated in the study. Abstinence from cigarette smoking was defined as presenting with a CO of ≤11 ppm. This CO level has been used previously as a criterion (Stitzer et al., 1986) and has been recommended by the manufacturer of a CO detector (Bedfont Scientific Ltd., 1995). Nevertheless, it is possible for individuals to smoke a limited amount and still present with a CO of ≤11 ppm, but we deemed this risk of false negatives to be more acceptable than the risk of false positives that might be obtained if the abstinence criterion were set lower. Participants in all three groups were provided with immediate feedback as to their CO level at each trial. Saliva samples were also collected from subjects on the Friday afternoon preceding the Monday on which they began the study and during their last visit of the study week. These samples were used to assay levels of cotinine, a nicotine metabolite. At each visit, participants were offered a supply of their own brand of cigarettes, and a CO reading was obtained.

Participants in the progressive group earned money according to the following schedule: The first time they presented with a CO that indicated abstinence, they received $3.00. Each subsequent consecutive CO sample that indicated abstinence increased the amount of money they received by $0.50. In addition, every third consecutive CO that was ≤11 ppm earned a $10.00 bonus. Thus, if their first CO was ≤11 ppm, they earned $3.00; if their second CO was ≤11 ppm, they earned $3.50; if their third CO was ≤11 ppm, they earned $14.00, if their fourth was ≤11 ppm they earned $4.50, and so forth. If participants presented with a CO that was over 11 ppm, payment was withheld and the value of payment available for the next CO ≤11 ppm was reset to the initial $3.00 level. This reset contingency was designed to discourage resumption of drug use once abstinence was achieved. Three consecutive COs indicating abstinence following a reset returned the payment schedule to the value at which the reset occurred. The rationale for this component was to support efforts to achieve abstinence again following a reset. Participants were informed in advance of the payment schedule and the criterion needed to earn reinforcement.

Participants in the fixed group were paid $9.80 every time they presented with a CO indicating abstinence. There were no bonuses for consecutive abstinences and there were no resets. The total amount of reinforcement that was available for subjects in the Progressive and fixed groups was equivalent. Participants were informed in advance of the payment schedule and the criterion needed to earn reinforcement.

The schedule of payment to participants in the control group was yoked to the average payment obtained by the first 10 participants assigned to the progressive group and was delivered independent of CO levels. However, participants in the control group were encouraged to try to cut their CO levels down to ≤11 ppm.

Instructions to the participants were designed to be as similar as possible across the three groups. In the progressive and fixed groups, participants were told that to receive money at each visit, they would have to present with a CO ≤11 ppm. The appropriate schedule of reinforcement was then explained as succinctly as possible, and participants were provided with a brief written description of the schedule in effect for their group. Participants in the control group were told that they would receive money independent of their CO readings but that we wanted them to attempt to cut their CO levels down to ≤11 ppm. Control group participants were provided with a written description of the amount of money available to them for each of their 15 visits.

Money earned via the aforementioned reinforcement schedules was paid in cash immediately following each CO assessment. Participants were given an additional $50.00 check upon completion of the study.

Data Analysis

A one-way analysis of variance (ANOVA) was conducted to examine the influence of reinforcement schedule on mean percentages of trials that participants in the three groups provided COs ≤11 ppm. Because these data were in percentage form, an arcsine transformation was performed before the ANOVA was conducted. Pairwise comparisons (Fisher's LSD, $p < .05$) were conducted across groups to discern specific between-group differences. A Kruskal-Wallis test was used to compare the groups in mean changes in cotinine levels from the start to the end of the 5-day study period. This nonparametric test was used because of the failure of the cotinine data to satisfy the normality assumption associated with the analysis of variance. Pairwise comparisons (Wilcoxon rank sum test, $p < .05$) were conducted across groups to discern specific between-group differences.

Chi-square tests were used to examine group differences in the proportion of participants able to achieve three consecutive COs ≤11 ppm (i.e., 24 hr of continuous abstinence), the proportion of participants who resumed smoking after they had achieved 24 hr of continuous abstinence, and the proportion of participants who were continuously abstinent across all 15 CO tests during the 5-day study period.

RESULTS

The efficacy of response-dependent reinforcement for increasing drug abstinence was evident in the comparison of mean percentages of CO readings ≤11 ppm across the three groups, $F(2, 57) = 18.8$, $p < .0001$. Mean abstinence levels in the progressive and fixed groups differed significantly from those in the control group (Fisher's LSD, $p < .05$), but not from each other (Figure 1, upper panel). These differences in abstinence levels were supported by significant group differences in mean decreases in cotinine levels during the 1-week study period ($\chi^2 = 6.6$, $df = 2$, $p = .04$). Again, the progressive and fixed groups differed significantly from the control group (Wilcoxon rank sum test $p < .05$), but not from each other (Figure 1, lower panel).

Differential efficacy of the two response-dependent schedules of reinforcement in sustaining abstinence was discernible in comparisons of the percentages of participants in the three groups who resumed smoking following a period of initial abstinence (i.e., first three consecutive COs ≤11 ppm). Consistent with the observations on mean abstinence levels, significantly more participants in each of the response-dependent groups achieved a period of initial abstinence than in the noncontingent control group: 90% ($n = 18$), 100% ($n = 20$), and 55% ($n = 11$) of participants assigned to the progressive, fixed, and control groups, re-

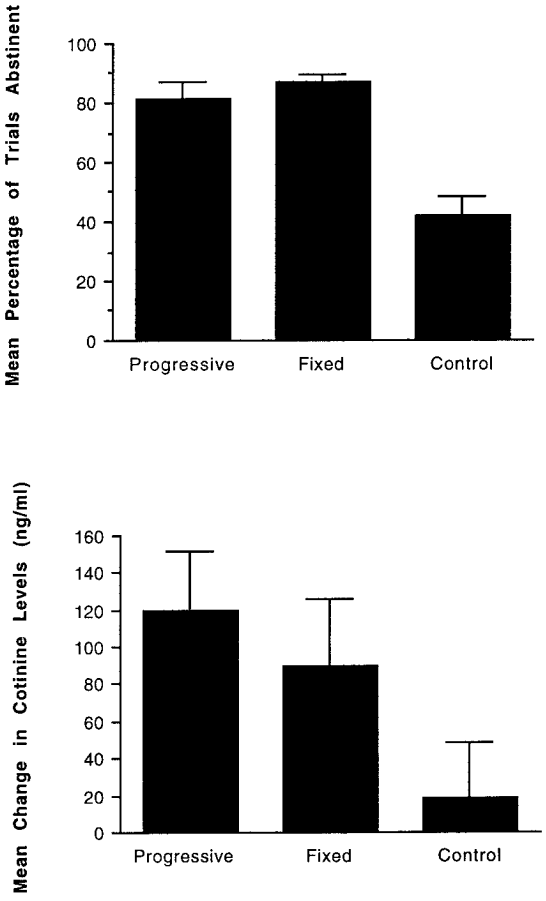

Figure 1. Mean percentage of 15 CO test trials on which participants in each group were abstinent (CO ≤ 11 ppm) during the course of the 5-day study period (upper panel). Mean decrease in salivary cotinine level in each group over the course of the 5-day study period (lower panel). Error bars represent the standard error of the mean (*SEM*).

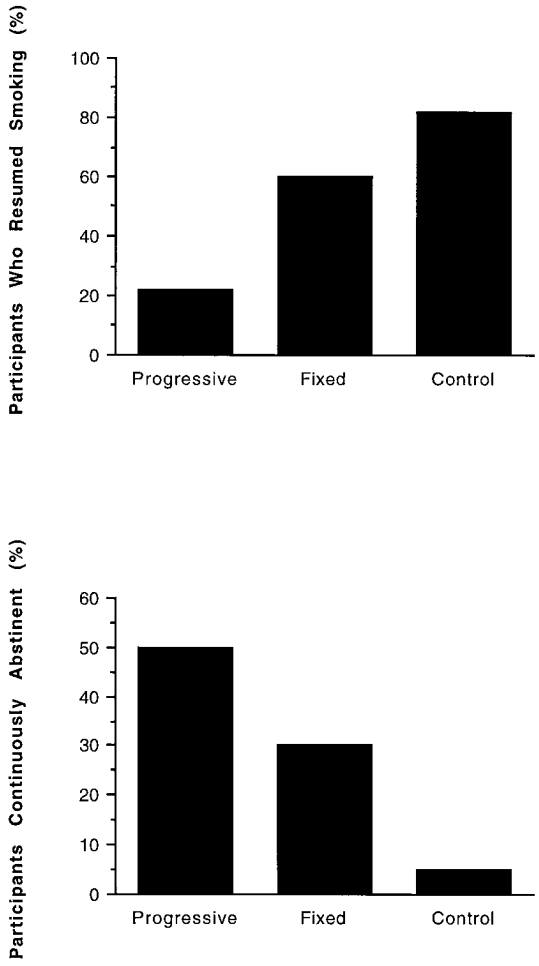

Figure 2. Percentage of participants in each group who obtained three consecutive abstinences and subsequently resumed smoking (upper panel). Percentage of participants in each group who were abstinent (CO ≤ 11 ppm) on all 15 trials during the course of the 5-day study (lower panel).

spectively, achieved a period of initial abstinence ($\chi^2 = 14.92$, $df = 2$, $p < .01$). However, only 22% ($n = 4$ of 18) of participants in the progressive group who achieved an initial period of abstinence resumed smoking during the 5-day study period compared to 60% ($n = 12$ of 20) and 82% ($n = 9$ of 11) of participants in the fixed and control groups ($\chi^2 = 10.80$, $df = 2$, $p < .01$). That difference between the progressive versus the fixed and control groups achieved statistical significance ($\chi^2 = 5.5$, $df = 1$, $p < .02$; $\chi^2 = 9.8$, $df = 1$, $p < .01$); the fixed and control groups did not differ significantly on this measure (see upper panel of Figure 2). It is important to note that this difference between the progressive versus the fixed and control groups was not unique to a particular definition of abstinence. When abstinence was defined as the first negative CO, for example, 35% of participants in the progressive group resumed smoking compared to 75% and 95% of participants in the fixed and control groups. Similarly, when abstinence was defined as the first two consecu-

tive negative COs, the percentage of participants in the progressive group who resumed smoking was 35% compared to 65% and 92% of participants in the fixed and control groups.

Group comparisons on the percentages of participants in each group who were able to sustain abstinence throughout the entire 5 days of testing further supported the efficacy of response-dependent reinforcement and suggested that the schedule of reinforcement may be important as well: 50% ($n = 10$), 30% ($n = 6$), and 5% ($n = 1$) of subjects in the progressive, fixed, and control groups, respectively, achieved the maximum duration of 15 consecutive CO tests at ≤11 ppm ($\chi^2 = 10.0$, $df = 2$, $p < .01$). The progressive and fixed groups differed significantly from the control group ($\chi^2 = 10.16$, $df = 1$, $p < .01$; $\chi^2 = 4.329$, $df = 1$, $p < .04$), but the differences between the progressive and fixed groups, although in the predicted direction, did not achieve statistical significance ($\chi^2 = 1.67$, $df = 1$, *ns*) (see lower panel of Figure 2).

DISCUSSION

The results demonstrate that contingent reinforcement can increase abstinence in chronic drug users. Participants in the progressive and fixed groups who received response-dependent payment were abstinent on average for greater than 80% of the CO tests administered, which was substantially more than the abstinence levels achieved by participants in the control group who received noncontingent payment. Those differences were also verified by mean reductions in salivary cotinine levels, with participants in the progressive and fixed groups showing greater reductions than those in the control group. These results are consistent with prior reports on the efficacy of reinforcement in reducing cigarette smoking (Rand, Stitzer, Bigelow, & Mead, 1989; Stitzer & Bigelow, 1982; Stitzer et al., 1986; Winett, 1973) and other forms of stimulant drug self-administration in humans in naturalistic settings (Higgins, Budney, et al., 1994; Silverman, Higgins, et al., 1996). They are also consistent with results from studies conducted with humans and nonhumans in laboratory settings demonstrating that availability of alternative nondrug reinforcers can effectively reduce stimulant self-administration (Bickel, DeGrandpre, Higgins, Hughes, & Badger, 1995; Carroll, Lac, & Nygaard, 1989; Higgins, Bickel, & Hughes, 1994; Nader & Woolverton, 1991).

The present results suggest that the schedule of reinforcement delivery may be an important determinant of resumption of smoking (i.e., relapse) following an initial period of abstinence. The reinforcement contingency used with the progressive group linked increases and decreases in reinforcement magnitude directly to the number of consecutive abstinent CO readings and was associated with the lowest number of participants who resumed smoking following an initial period of abstinence. The reinforcement contingencies used with the other two groups either specified no relationship between abstinence and reinforcement (control group) or did so in a manner that failed to differentially reinforce submission of consecutive negative COs (fixed group). Those two groups were both significantly below the progressive group in terms of the number of participants who resumed smoking following three consecutive abstinences. This suggests not only that response-dependent reinforcement is important in achieving abstinence, but that the specific contingent arrangement between abstinence and reinforcement magnitude can determine the likelihood of remaining abstinent. As was noted above, this finding does not appear to be an artifact of how we defined initial abstinence, because similar effects were observed with at least two other definitions.

A major goal of substance abuse treatment is to prevent resumption of drug use following an initial period of abstinence. For obvious ethical reasons that do not apply to the model used in this study, experimental studies of factors that influence relapse in humans are rare (but see Chornock, Stitzer, Gross, & Leischow, 1992). Even rarer are analyses of relapse in terms of basic behavioral processes, which we think is an important research area to pursue. The present results suggest that the relationship between the magnitude of reinforcement potentially lost by the resumption of drug use may be an important determinant of the probability of relapse. Participants in the progressive group forfeited a greater magnitude of reinforcement if they resumed drug use following an initial period of abstinence than did participants in the other two groups. For illustration purposes, consider the group differences in reinforcement loss associated with a positive CO following six consecutive negative tests on the initial six trials. In the control and fixed groups, the loss was fixed and was zero and $9.80, respectively. In the progressive group the loss was $33.50, and the magnitude of the loss increased as the number of consecutive negative tests increased. Although this finding is logical, we know of no prior experimental studies that have demonstrated the potential influence of reinforcement magnitude and loss on the resumption of drug use following abstinence. Considering the importance of improving our understanding of the determinants of relapse, we feel that this is a potentially important observation.

With regard to the percentage of participants who were abstinent throughout the entire test period, there was a trend for participants in the progressive group to perform better than participants in the fixed group, and both performed better than participants in the control group. The failure to declare the difference between the progressive and fixed groups statistically significant on this measure may have been due to our relatively small sample sizes and attendant lack of statistical power. Considering that the trend was in the predicted direction, this observation merits replication with a larger sample. Differences in the amount of continuous abstinence achieved as a function of varying the schedule of response-dependent reinforcement have been reported previously regarding cocaine use (Silverman, Wong, et al., 1996), but not, to our knowledge, for cigarette smoking or other forms of drug self-administration. Identifying strategies to facilitate continuous drug abstinence is an important challenge, considering that even small amounts of drug use early in the process of trying to discontinue smoking and other forms of stimulant use is a significant negative predictor of long-term abstinence (Budney, Higgins, Wong, & Bickel, 1996; Chornock et al., 1992; Hughes et al., 1992).

The reinforcement schedule used with participants in the progressive group of the present study was based on a schedule that is efficacious in promoting continuous cocaine abstinence in cocaine-dependent patients (Higgins et al., 1993; Higgins, Budney, et al., 1994; Silverman, Higgins, et al., 1996). Thus, its efficacy with cigarette smokers in the present study extends the generality of this reinforcement schedule to another type of drug self-administration. This demonstration that the same procedure is effective in promoting abstinence from different types of drug use lends empirical support to the position that a common set of processes operates across the different types of drug abuse.

The high rates of smoking observed in the present study, especially in the control group, are similar to the >75% relapse rates observed within the 1st week for smokers who attempt to quit on their own (Hughes et al., 1992). This consistency across studies suggests that the high relapse rates in the

present study are not an artifact of participants lacking a commitment to quit, but, rather, underscore the difficulty of achieving even a short period of continuous abstinence from smoking.

The current procedure of using cigarette smoking to experimentally analyze factors that affect drug abstinence may represent a pragmatic use of what are becoming progressively limited research resources. Such studies cannot supplant randomized clinical trials, but they can provide a useful model for experimentally examining different variables or processes involved in drug abstinence and relapse. Results from the present study demonstrate the sensitivity of this procedure to variations in a behavioral process. It may be similarly sensitive and useful for addressing questions about the influence of pharmacological variables on abstinence, including potential pharmacotherapies like nicotine replacement treatment as well as use of drugs that might disrupt abstinence (Chornock et al., 1992). The reinforcement schedule used with the progressive group might be particularly useful in this regard, because the 50% success rate of participants achieving continuous abstinence throughout the study period under that arrangement appears to be optimal for detecting either facilitation or disruption of continuous abstinence.

Several aspects of the generality of the present results merit comment. First, there is the question of whether results observed with cigarette smokers have generality to other types of drug abuse. As was mentioned above, procedures similar to those employed in the current study have been used to reduce consumption of a variety of drugs (e.g., benzodiazepines, Stitzer et al., 1979; cocaine, Higgins, Budney, et al., 1994; nicotine, Stitzer et al., 1986; and opioids, Stitzer et al., 1993). Thus, there is reason to expect that similar results would be obtained should the scheduling arrangements employed in the current study be investigated with other forms of drug use. Second, the generality of the present results may be limited by using individuals who were not trying to quit smoking. Instead of the social and health-related contingencies that are likely to influence attempts at smoking cessation in naturalistic settings, contrived contingencies were applied to encourage abstinence in this study. Although there is a long and successful tradition of using contrived contingencies to study behavioral processes, whether the present results extend to individuals who are trying to quit smoking is an empirical question. A third and related issue is the use of money to initiate and sustain abstinence in the present study. Here, too, contrived conditions were employed to conveniently study processes involved in cigarette smoking. The intent was not to encourage the use of monetary reinforcement in clinical interventions per se. However, reinforcers of this type (e.g., vouchers, lottery tickets) are being explored with difficult-to-treat subpopulations of cigarette smokers such as illicit drug abusers (Shoptaw, Jarvik, Ling, & Rawson, 1996) and patients with chronic obstructive pulmonary disease (Crowley, MacDonald, Zerbe, & Petty, 1991). Thus, direct application of monetary and related reinforcers may be reasonable under some clinical circumstances. Finally, the short duration of abstinence examined in this study might limit the generality of the present results. The 5-day duration was selected for two reasons: (a) to minimize the influence of extraneous events that might affect cigarette smoking (e.g., illness, shift work), and (b) because relapse and the peak of the nicotine withdrawal syndrome generally occur within 5 days of initial cessation (Fung, Schmid, Anderson, & Lau, 1996; Hughes et al., 1992). For these reasons, the 5-day duration of this study appears to be sufficient to provide a rigorous assessment of the variables in question. However, it is possible that the

variables that influence early abstinence and relapse differ from those that affect longer periods of abstinence and relapse. Nevertheless, both are important, and the majority of relapse is of the early variety.

REFERENCES

Bedfont Scientific Ltd. (1995). *Bedfont Scientific Ltd. operators manual for mini and micro smokerlyzers. Breath testing CO monitors for smoking education and cessation applications.* Kent, England: Author.

Bickel, W. K., DeGrandpre, R. J., Higgins, S. T., Hughes, J. R., & Badger, G. J. (1995). Effects of simulated employment and recreation on drug taking: A behavioral economic analysis. *Experimental and Clinical Psychopharmacology, 3,* 467–476.

Bickel, W. K., DeGrandpre, R. J., Hughes, J. R., & Higgins, S. T. (1991). Behavioral economics of drug self-administration. II. A unit-price analysis of cigarette smoking. *Journal of the Experimental Analysis of Behavior, 55,* 145–154.

Bigelow, G. E., Stitzer, M. L., & Liebson, I. A. (1984). The role of behavioral contingency management in drug abuse treatment. In J. Grabowski, M. L. Stitzer, & J. E. Henningfield (Eds.), *Behavioral intervention techniques in drug abuse treatment* (pp. 36–52). Rockville, MD: National Institute on Drug Abuse.

Budney, A. J., Higgins, S. T., Wong, C. J., & Bickel, W. K. (1996). Early abstinence predicts outcome in behavioral treatment for cocaine dependence. In L. S. Harris (Ed.), *Problems of drug dependence 1995* (p. 98). Rockville, MD: National Institute on Drug Abuse.

Carroll, M. E., Lac, S. T., & Nygaard, S. L. (1989). A concurrently available nondrug reinforcer prevents the acquisition or decreases the maintenance of cocaine-reinforced behavior. *Psychopharmacology, 97,* 23–29.

Chornock, W. M., Stitzer, M. L., Gross, J., & Leischow, S. (1992). Experimental model of smoking re-exposure: Effects on relapse. *Psychopharmacology, 108,* 495–500.

Crowley, T. J., MacDonald, M. J., Zerbe, G. O., & Petty, T. L. (1991). Reinforcing breath carbon monoxide reductions in chronic obstructive pulmonary disease. *Drug & Alcohol Dependence, 29,* 47–62.

Cummings, K. M., Jaen, C. R., & Giovino, G. (1985). Circumstances surrounding relapse in a group of recent exsmokers. *Preventive Medicine, 14,* 195–202.

Fagerstrom, K. O., & Schneider, N. G. (1989). Measuring nicotine dependence: A review of the Fagerstrom tolerance questionnaire. *Journal of Behavioral Medicine, 12,* 159–182.

Ferster, C. B., & Skinner, B. F. (1957). *Schedules of reinforcement.* New York: Appleton-Century-Crofts.

Fung, Y. K., Schmid, M. J., Anderson, T. M., & Lau, Y.-S. (1996). Effects of nicotine withdrawl on central dopaminergic systems. *Pharmacology Biochemistry and Behavior, 53,* 635–640.

Griffiths, R. R., Bigelow, G. E., & Henningfield, J. E. (1980). Similarities in animal and human drug taking behavior. In N. K. Mello (Ed.), *Advances in substance abuse behavioral and biological research* (pp. 1–90). Greenwich, CT: JAI Press.

Higgins, S. T., Bickel, W. K., & Hughes, J. R. (1994). Influence of an alternative reinforcer on human cocaine self-administration. *Life Sciences, 55,* 179–187.

Higgins, S. T., Budney, A. J., Bickel, W. K., Foerg, F., Donham, R., & Badger, G. J. (1994). Incentives improve outcome in outpatient behavioral treatment of cocaine dependence. *Archives of General Psychiatry, 51,* 568–576.

Higgins, S. T., Budney, A. J., Bickel, W. K., Hughes, J. R., Foerg, F., & Badger, G. (1993). Achieving cocaine abstinence with a behavioral approach. *American Journal of Psychiatry, 50,* 763–769.

Higgins, S. T., Stitzer, M. L., Bigelow, G. E., & Liebson, I. A. (1986). Contingent methadone delivery: Effects on illicit opiate use. *Drug and Alcohol Dependence, 17,* 311–322.

Hughes, J. R., Gulliver, S. B., Fenwick, J. W., Valliere, W. A., Cruser, K., Pepper, S., Shea, P., Solomon, L. J., & Flynn, B. S. (1992). Smoking cessation among self-quitters. *Health Psychology, 11,* 331–334.

Lamb, R. J., Iguchi, M. Y., & Kirby, K. C. (1995). Effects of target criteria and reinforcement magnitude in reinforcing reduced breath CO levels in smokers not seeking treatment. In L. S. Harris (Ed.), *Problems of drug dependence 1994* (p. 272). Rockville, MD: National Institute on Drug Abuse.

Marcus, B. A., & Vollmer, T. R. (1995). Effects of differential negative reinforcement on disruption and compliance. *Journal of Applied Behavior Analysis, 28,* 229–230.

Nader, M. A., & Woolverton, W. L. (1991). Effects of increasing the magnitude of an alternative reinforcer on drug choice in a discrete-trials procedure. *Psychopharmacology, 105,* 169–174.

Rand, C. S., Stitzer, M. L., Bigelow, G. E., & Mead, A. M. (1989). The effects of contingent payment and frequent workplace monitoring on smoking abstinence. *Addictive Behaviors, 14,* 121–128.

Repp, A. C., Felce, D., & Barton, L. E. (1991). The effect of initial interval size on the efficacy of DRO schedules of reinforcement. *Exceptional Children, 57,* 417–425.

Shoptaw, S., Jarvik, M. E., Ling, W., & Rawson, R. A. (1996). Contingency management for tobacco smoking in methadone-maintained opiate addicts. *Addictive Behaviors, 21,* 409–412.

Silverman, K., Higgins, S. T., Brooner, R. K., Montoya, I. D., Cone, E. J., Schuster, C. R., & Preston, K. L. (1996). Sustained cocaine abstinence in methadone maintenance patients through voucher-based reinforcement therapy. *Archives of General Psychiatry, 53,* 409–415.

Silverman, K., Wong, C. J., Umbricht-Schneiter, A., Montoya, I., Schuster, C. R., & Preston, K. L. (1996). Voucher-based reinforcement of cocaine abstinence: Effects of reinforcement schedule. In L. S. Harris (Ed.), *Problems of drug dependence 1995* (p. 97). Rockville, MD: National Institute on Drug Abuse.

Stitzer, M. L., & Bigelow, G. E. (1982). Contingent reinforcement for reduced carbon monoxide levels in cigarette smokers. *Addictive Behaviors, 7,* 403–412.

Stitzer, M. L., & Bigelow, G. E. (1983). Contingent payment for carbon monoxide reduction: Effects of pay amount. *Behavior Therapy, 14,* 647–656.

Stitzer, M. L., & Bigelow, G. E. (1984). Contingent reinforcement for carbon monoxide reduction: Within-subjects effects of pay amount. *Journal of Applied Behavior Analysis, 17,* 477–483.

Stitzer, M. L., Bigelow, G. E., & Liebson, I. (1979). Reducing benzodiazepine self-administration with contingent reinforcement. *Addictive Behaviors, 4,* 245–252.

Stitzer, M. L., Iguchi, M. Y., Kidorf, M., & Bigelow, G. E. (1993). Contingency management in methadone treatment: The case for positive incentives. In L. S. Onken, J. D. Blaine, & J. J. Boren (Eds.), *Behavioral treatment for drug abuse and dependence* (pp. 19–36). Rockville, MD: National Institute on Drug Abuse.

Stitzer, M. L., Rand, C. S., Bigelow, G. E., & Mead, A. M. (1986). Contingent payment procedures for smoking reduction and cessation. *Journal of Applied Behavior Analysis, 19,* 197–202.

Winett, R. A. (1973). Parameters of deposit contracts in the modification of smoking. *The Psychological Record, 23,* 49–60.

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STUDY QUESTIONS

1. According to the authors, what variables have been manipulated in research on contingency management with substance abusers, and which of these variables were manipulated in the present study?

2. Why was cigarette smoking selected as the target behavior of interest?

3. What was the primary dependent variable? Generally speaking, what type of measure does this represent? How was abstinence operationally defined and how were the data summarized?

4. What were the main differences in reinforcement schedules for the progressive, fixed, and control groups? Also, is it possible that the study could have been conducted using within-subject (rather than between-subjects) methodology and, if so, what type of experimental design would be most appropriate?

5. The name assigned to the schedule for the progressive group (progressive rate of reinforcement) bears resemblance to a reinforcement schedule that is sometimes used in basic research, the progressive-ratio schedule. Describe the common element in these two types of schedules and the key feature that distinguishes them.

6. What were the effects of (a) contingent versus noncontingent reinforcement on abstinence and (b) progressive versus fixed rates of contingent reinforcement on sustained abstinence?

7. How did the authors account for observed differences in sustained abstinence between the progressive and fixed groups?

8. The authors suggested that progressive rates of reinforcement have also been effective in promoting cocaine abstinence, indicating that a "common set of processes" may operate across different types of drug abuse. Comment as to why procedural effectiveness may or may not be indicative of underlying process, using a different (nondrug) example.

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